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WATER TESTING STATIONS¹

BY W. T. McCLENAHAN AND R. S. RANKIN

The development of water purification methods has been accomplished principally with the aid of water-testing stations. An engineer in designing a water purification plant prefers to follow where possible, the indications afforded by the experience of others. Frequently, however, he has no safe guide and recourse is best had to actual tests on a working scale as nearly as possible comparable to real conditions. The critical factors in the design can thus be determined. These may be hydraulic values, such as velocities, settling periods, rates of application; biological values, such as bacterial removal; or physical values, such as the removal of tastes and odors. Briefly, the development of the testing station has been from the general to the specific. The early stations endeavored to formulate fundamental principles which have been applicable to a certain extent to all filtration plants. With these principles established, the testing station has been applied to more detailed and specific problems.

DESIGN AND CONSTRUCTION

The size of the testing station which it is advisable to build depends on the nature of the tests and the funds available. In general, a testing station is a miniature replica of a complete purification plant. Sometimes, however, the tests are run on parts of a completed plant prior to enlargement, or a portion of one of the component parts of a plant is built in advance for test purposes. When it is necessary to determine only the rates and areas required to make established basic principles applicable to local conditions, this method of testing would seem to offer great possibilities, first, because full-size units can be used for the tests, and, second, because the testing station can very often be built out of funds already appropriated for partial or complete treatment.

¹ Read before the Illinois Section on March 26, 1919.

When a small testing station is to be built, the purpose of the tests should be kept clearly in mind. A test run to investigate color removal, for instance, needs only to prove that it is possible to remove color. It is not necessary to produce absolutely sterile water in the testing station itself, for experience has shown that it is much more difficult to get sterile water from a small test filter than from the larger units used in regular filtration work. As long as the test demonstrates that the color can be removed and shows how it is to be done the plant has accomplished its mission.

A testing station should be compact, convenient, and easy of access to all parts. As far as practicable the course of the water through the plant should be progressive. Each step in the treatment process should be in logical sequence, in order that the work of the operator may be simplified and that it may be easier to watch and understand. This is particularly important when the operator is a non-technical man.

The designer should keep in mind that a plant of this kind is often subjected to radical alterations. The baffling and piping arrangements are most often affected, and the chemical used for treating purposes may have to be changed also. In this case, a change in the method of applying or in its point of application may be required.

Because of the temporary character of a testing station, the first cost is relatively very important, while durability of material and cost of operation are not so important. Wooden construction is quite suitable, sheet iron is useful and black iron pipe is often satisfactory. The salvage value after the plant is dismantled may, however, call for better material than would otherwise be used. Obviously, the material and construction should be substantial and good enough to give satisfactory service and to last throughout the period of test.

Recently, the firm of Pearse and Greeley have designed and built two small testing stations to study unusual problems in water purification. They show the value of such tests when little literature or experience is available.

WHITING TESTING STATION

Whiting, a city of 8200 people, is located along the south shore of Lake Michigan in the heart of a great industrial district. Sur-

rounding it are Indiana Harbor, East Chicago and Hammond. Not far distant lie South Chicago and Gary. At present all the sewage from this great manufacturing region finds its way into Lake Michigan, but the Calumet Sag Canal promises some relief in the near future. Some of the industries produce large quantities of troublesome wastes, notably several chemical works, a glucose factory, and the great steel mills. The most troublesome waste, however, is that from the Standard Oil refinery located in Whiting, which imparts a very objectionable taste and odor to the city water. The amount of oil actually existing in the water is exceedingly small and is very difficult to detect by any chemical means, nevertheless the effect is quite apparent to the consumer.

Most of the oil is said to come from the agitators where motor spirits are clarified. Soda and sulphuric acid are added in this refining process and the resulting sulphates are washed out into the lake and form what is called "soap" or "white water." This white water carries off small quantities of oil in mechanical suspension, some in the form of an emulsion and some in colloidal solution. Portions of the oil are volatile.

The city water supply is drawn through a 66-inch brick tunnel extending out into the lake about 2400 feet. At times, the white water described above discolors the lake as far as the intake and the water is rarely without some odor or taste.

The problem for design was this, given a city water supply contaminated by a variety of unusual wastes, with oil waste predominating, to design a filter plant effective in removing odors and tastes as well as the bacterial content. The purpose of the testing station was to study this problem along the following lines: (1) The effect of aeration on the odor and taste. (2) The kind and amount of chemical to be used and its effect on the odor and taste. (3) The period of sedimentation and the time of contact giving the best results. (4) Any peculiarities that might develop in the treatment of water contaminated by oil.

The following summary of information gives data regarding the design:

Aeration. Size of collecting platform, 14 by 13 feet. Nozzle used, No. 9 Spraco. Pressure at base of nozzle, 8 pounds. Water rate, $8\frac{1}{2}$ gallons per minute.

Chemical treatment. Chemical used, alum, admitted between aerator and coagulation basin. Strength of stock solution, 10 per

cent. Strength of solution fed, 1.25 per cent. Method of feeding, through a small hole drilled in the side of a $\frac{1}{2}$ -inch brass tube stuck through a rubber cork in the bottom of a wooden bucket. Head on orifice maintained by means of a fountain similar to the inverted water bottle often found in offices. Amount of chemical fed in water, from 0.6 grain to 1 grain per gallon of water treated.

Coagulation basins. Number used, 2. Size of each basin, 5 feet 6 inches x 8 feet x 2 feet 9 inches deep inside measurements. Depth of water, 31 inches. Capacity each basin, 825 gallons. Capacity in hours, 1 hour 40 minutes each when tanks were run in series (3 hours 20 minutes total) or 3 hours 30 minutes each when run in parallel. Number of baffles in each tank, 1 lengthwise at first with 2 passageways, later changed to have 3 baffles with 4 passageways. Velocity of flow, when run in parallel, 0.076 feet per minute with single baffle, and 0.172 feet per minute with triple baffle; when run in series, 0.152 feet per minute with single baffle, and 0.344 feet per minute with triple baffle.

Filter. Number, 1; area, 4 square feet; filtering rate, 8 gallons per minute; underdrain system used, Harrisburg type with pipe grid; depth of gravel, 8 inches; depth of sand, 30 inches; wash, hand-controlled from barrel storage; rate of wash, 15 gallons per square foot per minute; method of supplying wash water, hand pump lifting water from filtered water barrel to wash water barrels; method of rate control, float valve and orifice.

The results of aeration showed that the improvement in the water was not at all uniform. Its efficacy seemed dependent upon the direction and velocity of the wind which, when it blew across the plant of the Standard Oil Company, not only caused the air to become heavily laden with oily odors but also drove before it a great deal of sand and cinders which had become coated with oil. Under such conditions the spray actually washed oil out of the atmosphere instead of giving up that which it already contained. Nevertheless the aeration seemed helpful at all times for the water required a smaller amount of chemical to accomplish the final removal in the coagulation basins and filters, due perhaps to a breaking down of the emulsion.

Alum was the only chemical tried and it proved successful. As the oil which remained in the water after aeration was probably removed by adsorption, that is by sticking to the flocculent precipitate of alum, any other coagulant of the same general character

would doubtless have done as well. It was not thought worth while to go further into the matter. A fair average of the amount of alum required was about 0.7 grain per gallon of water treated.

In regard to sedimentation and the period of contact, it seemed that the oil required some time to attach itself to the coagulant, and when the floc was kept in suspension longer than in the common practice, a smaller amount of alum could do the same work.

Among the peculiarities which developed during the test, the most important was the necessity for frequent washing to maintain the normal rate of filtration. The filter acted as though it were air-bound. This was probably due to the oily floc forming a water-tight film over the surface of the sand, for it was discovered that by lightly raking the surface of the sand the filtering rate was restored and the loss of head returned to nearly normal. Later it was found that the same result was obtained by shaking the filter, i.e., by simply opening and closing the wash-water valve without actually washing the filter. In this way the period of service between washings was increased from six to sixteen hours, with a consequent reduction in the amount of wash water used.

Difficulty was also experienced in making satisfactory analyses of the samples. Since no other method was available for detecting oil in such minute quantities, appeal had to be made to the senses of taste and smell. Obviously, these senses are somewhat unreliable. However the tests were made independently by three different persons so that the results were well checked. It was found that it was impossible to judge odors in Whiting, because of the atmospheric conditions, so the samples were brought to Chicago for judging. Conclusions from the tests proved that the taste and odor could be thoroughly removed when the modifications of filter practice noted above were put into effect.

MIDLAND TESTING STATION

Another water testing station has just been constructed recently at Midland, Mich., by Pearse and Greeley.

Midland is a town of about 10,000 inhabitants near the center of a brine-well district. The Chippewa and the Tittabawassee Rivers unite in Midland. The Chippewa is less turbid and colored than the Tittabawassee, but has a drainage area more thickly settled and, consequently, much more polluted. Both waters are fairly

hard. At present, Midland obtains its supply from the Chippewa River, principally because of its clearness.

The problem at Midland is in part as follows: (1) Determination of the more suitable supply, the Chippewa or the Tittabawassee Rivers. (2) Determination of best method of reducing the color of the Tittabawassee River, if that supply is selected. (3) Determination of the best method for reducing the alkalinity of either source.

The testing station consists essentially of two coagulating basins, a filter, and a filtered water storage tank. Supplementary to these are an inlet orifice box, a divided orifice box, one portion of the flow passing through a lime saturator and joining the other portion, a mixing trough, wash-water barrels, and a filter-rate controller of the adjustable float type. The supply is obtained from the river through a small electric-driven centrifugal pump, and delivered to the inlet orifice box. The following summary of the different devices furnishes an outline of the essential features in the design and operation:

Lime. Admitted as lime water. Quantity used, approximately 8 grains per gallon. Method of feeding, by diverting a portion of flow (about one-tenth) through a lime saturator, and uniting it with the remaining portion as lime water.

Alum. Point of application, between the two coagulating basins. Method of feeding, a 20-liter bottle with side outlet controlled by adjustable screw cock. A glass tube through a cork in the top which terminated in an upturned gooseneck near the bottom supplied the air and regulated the head on the outlet. This bottle was capable of very fine adjustment.

Lime saturator. Size, 16 inches in diameter at the top, 4 inches in diameter at the bottom, depth 30 inches. Flow period, 30 minutes to one hour. Method of admitting lime, as a 10 per cent milk of lime mixed in barrel above.

Mixing troughs. Number of passages, 5. Each passage 3 inches wide, 3 inches water depth and 6 feet long. Period of mixing, approximately 3 minutes. Each passage was baffled with 1-inch cleats spaced 3 inches on centers and had a slope of one inch from end to end.

Coagulating basins. Number used, 2. Size and capacity, the same as of those used at Whiting. Period of flow used in tests, 8 hours and 6 hours.

Filter. Number of filters, 1. Material, galvanized iron. Filtering area, 18 inches in diameter, 1.75 square feet. Filtering rate, 3.5 gallons per minute. Underdrains, Harrisburg type.

Rate controller. Float-operated valve on effluent of filter.

Wash water. Supply, two barrels on a platform about 18 feet above the filter underdrains. Amount used in each wash, 100 gallons. Wash-water pump, electric-driven centrifugal.

The addition of 8 grains of lime per gallon with a sedimentation period of about 6 hours has demonstrated that the alkalinity of the raw water may be reduced from about 175 p.p.m. to 50 or 60 p.p.m. in the filtered water.

Unfortunately, on account of ice in the river, the tests on the reduction of color had to be discontinued but will be resumed at an early date. With lime alone the color was reduced from 45 to 15 p.p.m. Alum treatment has not yet started.

The saturator method of applying lime water works very well and, where such relatively small quantities of lime are required, it is much superior to the orifice box method of feeding a milk of lime solution. However, it requires a certain amount of care to determine when a new batch of lime shall be admitted to the saturator. The amount of lime wasted through inefficient saturation is negligible in a testing station.

A small laboratory was fitted up in conjunction with the station. Alkalinity tests on the raw water, lime water, coagulated water and filtered water were run at frequent intervals. Anything wrong or unusual in the operation was apparent to the operator at once. The solutions were made up so that no computations had to be made to interpret the results.

The testing station itself was housed in an old pump house, heated and lighted. This was a distinct advantage. The tests were run 24 hours of the day and thus approached actual working conditions.

COSTS

The accompanying table of costs of water testing stations is based on one published in "Sewage Disposal," by George W. Fuller, revised by Langdon Pearse in his lecture on "Experimental Engineering, Particularly the Construction of Testing Stations on Water and Sewage Problems" and brought up to date by the authors.

List of special American investigations on water and sewage purification

PLACE	DATE	WORK	COST
Lawrence, Mass.....	1887-11	Water and Sewage	\$195,000
Providence, R. I.....	1893-94	Water	5,000
Louisville, Ky.....	1895-97	Water	47,395
Reading, Pa.....	1897	Water	1,500
Pittsburg, Pa.....	1897-98	Water	36,386
Cincinnati, O.....	1898-99	Water	41,588
West Superior, Wis.....	1898-99	Water	2,000
Washington, D. C.....	1899-1900	Water	8,000
Richmond, Va.....	1900	Water	2,000
New Orleans, La.....	1900-01	Water	23,606
Philadelphia, Pa.....	1900-05	Water	172,000
Springfield, Mass.....	1901-03	Water	18,000
Harrisburg, Pa.....	1903-04	Water	25,000
Columbus, O.....	1904-05	Water and Sewage	44,000
Oakland, Calif.....	1907-08	Water	19,390
Ontario, Province of.....	1909-15	Water and Sewage	61,900*
Detroit, Mich.....	1916	Water	8,000†
Cleveland, O.....	1916	Water	4,000‡
Milwaukee, Wis.....	1918	Water	40,000§
Whiting, Ind.....	1917	Water	1,000

* Includes about \$14,000 for field work in Province.

† Does not include Operating cost of \$9,000 per year.

‡ Does not include Operating cost.

§ Appropriation.

Construction cost of testing stations

STATION	SUPPLY	TOTAL	REMARKS
<i>Water</i>			
Baltimore.....	Gravity	\$5,000	
Cincinnati.....	Gravity	19,717	Testing devices
		4,411	Laboratory building and equipment.
Detroit.....		8,000	
Harrisburg.....	Pumped	10,573	Including engine inspection
Jerome Park.....		7,825	(*)
Milwaukee.....	Pumped	8,282	Exclusive of piping, heating, etc.
Whiting, Ind.....	Pumped	500	
Midland.....	Pumped	500	
Cleveland.....	Pumped	4,000	

* Low bid, exclusive of filter washing machine.

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